DYNAMIC PROPERTIES OF MALAYSIAN PEAT SOIL BASED ON FIELD GEOPHYSICAL METHODS

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For my beloved wife, son, mother, father and families.

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ABSTRACT

The small strain dynamic properties of peat soil are a fundamental parameter related to the mechanical behavior of a structure constructed on peat ground. Lab-based studies are frequently used to determine the dynamic properties despite the risk of underestimating or overestimating the values due to sample disturbance. This study performed a geophysical method known as multichannel analysis of surface waves (MASW) to determine peat's in-situ dynamic properties. Meanwhile, seismic refraction (SR), electrical resistivity tomography (ERT) and peat sampler were conducted to delineate the peat stratigraphy. The study locations include Parit Nipah, Tanjung Piai, Pontian, Sedenak, Medan Sari and Klias. To ensure high-quality data was obtained, the optimum field configuration for the active MASW method was established for peat conditions. Based on the finding, high-resolution data were obtained using, dx=1m, X_1=1/2L, an active source of 7 kg sledgehammer with rubber plate, 5 data stackings, 4.5 Hz geophone type and 100 to 250 μs of the sampling interval. The optimum field configuration established resulted in higher accuracy data collection and analysis of the dynamic properties. The results showed that the value of V_s, V_p, G_{max} and E_{max} ranged from 24.5 to 67.1 m/s, 300 to 577 m/s, 0.4 to 7.1 MPa and 1.2 to 21.1 MPa, respectively. Correlations were also established between the dynamic properties and index properties of peat. There appears to be an excellent link between peat's dynamic properties and index properties. The dynamic properties show an increasing pattern with decreasing moisture, organic and fiber content. Meanwhile, an increase in specific gravity and bulk density results in an increase in dynamic properties. Overall, peat's dynamic properties were similar and in good agreement with the laboratory-based dynamic properties from the literature. Finally, the findings in this study contributed to improving the understanding of the dynamic behavior of peat especially for settlement prediction and embankment design.

ABSTRAK

Ciri-ciri dinamik ketegangan kecil tanah gambut adalah parameter asas yang berkait dengan sifat-sifat mekanikal struktur yang dibina di atas tanah gambut. Penentuan sifat-sifat dinamik tanah gambut kebiasaannya menggunakan ujikaji di makmal walaupun terdedah dengan risiko anggaran berlebihan dan berkurangan akibat sampel terganggu. Kaedah geofizik yang antaranya *multichannel analysis of surface waves (MASW)* telah diguna pakai dalam kajian ini untuk menentukan ciri-ciri dinamik gambut di tapak. Manakala *seismic refraction (SR), electrical resistivity tomography (ERT*) dan pensampel gambut dijalankan untuk mengenalpasti stratigrafi gambut. Lokasi kajian merangkumi Parit Nipah, Tanjung Piai, Pontian, Sedenak, Medan Sari dan Klias. Untuk memastikan ketepatan data, konfigurasi optimum di tapak untuk penggunaan *MASW* aktif untuk gambut telah dikaji. Berdasarkan dapatan, data resolusi tinggi diperoleh menggunakan, dx=1m, X_1=1/2L, sumber tenaga aktif tukul besi 7kg dengan plat getah, 5 tindihan data, jenis geofon 4.5 Hz, dan selang persampelan 100 ke 250 μs. Konfigurasi optimum yang diwujudkan berhasil mendapatkan data dan analisa yang lebih tepat. Hasil dapatan menunjukkan nilai V_s, V_p, G_{max} dan E_{max} berada dalam lingkungan masing-masing dari 24.5 ke 67.1 m/s, 300 ke 577 m/s, 0.4 ke 7.1 MPa dan 1.2 ke 21.1 MPa. Korelasi juga telah diwujudkan diantara ciri-ciri dinamik dan ciri-ciri indeks gambut. Kaitan khusus yang baik antara ciri-ciri dinamik dan ciri-ciri indeks gambut diperoleh. Ciri-ciri dinamik menunjukkan corak menaik dengan penurunan nilai kandungan kelembapan, kandungan organik dan kandungan serat. Manakala, kenaikan pada graviti spesifik dan ketumpatan basah menghasilkan ciri-ciri dinamik menaik. Secara keseluruhan, ciri-ciri dinamik gambut yang diperoleh berada pada lingkungan magnitud yang sama dan menyamai nilai yang diperoleh melalui uji kaji makmal dalam tinjauan literatur. Akhir sekali, hasil dapatan dalam kajian ini dapat menyumbang dalam menambah baik kefahaman ciri-ciri dinamik tanah gambut dan terutama melibatkan jangkaan mendapan dan rekabentuk tambakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	American society for testing and materials
dx	Receiver spacing
E_{max}	Maximum elastic modulus
ERT	Electrical resistivity tomography
FC	Fiber content
G_{max}	Maximum shear modulus
G_s	Specific gravity
L	Total spread length
MASW	Multichannel analysis of surface waves
OC	Organic content
SR	Seismic refraction
SNR	Signal-to-noise-ratio
USDA	U.S. Department of Agriculture
V_p	Primary wave velocity
V_s	Shear wave velocity
w	Moisture content
X_1	Source offset
ρ	Density
z_{max}	Maximum depth of penetration
λ_{max}	Maximum wavelength

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CHAPTER 1

INTRODUCTION

1.1 Preamble

Peatlands are recognized as challenging construction grounds in Malaysia. The distribution of peatlands in Malaysia is the 9th largest in the world, with 2.46 million hectares (Jon *et al.*, 2010; Mesri and Ajlouni, 2007). In recent years, the global peatland condition has been extensively studied to improve the current peatland area estimation. Xu *et al.* (2018) found that the current peatland estimation especially in Southeast Asian countries is lower as the peatland maps were mainly produced from the interpretation of satellite images with little ground survey data. However, due to limited available data, the estimation of the peatland area in Malaysia still refers to the data provided by Wetland International (Jon *et al.*, 2010). Sarawak contains the largest peatlands area, with approximately 1.7 million hectares, consisting of about 69 % of the total peatlands in Malaysia. Peninsular Malaysia and Sabah hold about 0.64 and 0.12 million hectares, estimated 26.2 and 4.8 %, respectively. Sabah and Johor are among the top states in Malaysia with a high volume of peatlands other than Sarawak. The distribution of peatlands in Malaysia is mainly in the coastal area and some in the inland area (Jon *et al.*, 2010). The peatlands are often avoided for construction as the understanding of their behavior and solution to encounter their problematic characteristic is very limited. The focus of city development in Malaysia is mainly on the coastal area, which increases the possibility of construction on peatlands. Thus, making dealing with peat soil unavoidable.

Commonly encountered problems involving construction on peat ground include bumpy roads due to differential settlement (Wijeyesekera *et al.*, 2016), embankment stability (Mohamad, Zainorabidin and Hassan, 2022), embankment failure due to large settlement (Abdurahman *et al.*, 2021) and long-term settlement (Jumien *et al.*, 2021). Understanding peat soil dynamic properties could provide a better understanding of its behavior, thus, minimizing the risk of failure during construction on peat ground.

Peat soil characteristics are different and challenging compared to other types of soils. Peat consists mainly of partially decomposed plant fragments and roots in their natural state. Peat also is characterized by very high water content, high organic content, high compressibility and low shear strength (Zainorabidin and Wijeyesekera, 2007). These characteristics cause conventional sampling methods and investigation challenges. Accessing sample collecting and getting high-quality, undisturbed samples are some of the obstacles. In addition, there is less knowledge on peat behavior since there is a lack of high-quality data. Peat behavior frequently results in differential settlement during construction, particularly when building roads. Significant short-term and long-term settlement causes major failure on structures constructed on peat ground. The impact of dynamic loading on peat determined this criterion. Because of this, it was essential for design evaluation and planning to comprehend how the peat's dynamic behavior affects the conception and construction of infrastructure. Moreover, understanding peat behavior will provide sufficient knowledge for optimum and economical design on peat ground.

The development of geophysical method investigation globally in the past decades has shown potential application in soft soil application. The ability of these methods to investigate the soil in its natural state mitigates the problems related to sample disturbance and difficulties of access for sampling. As mentioned by L'Heureux *et al.* (2013); Seed and Idriss (1972); Sun, Golesorkhi and Seed (1988), sample disturbance often compromised the results obtained and the risk of potential overestimation or underestimation of the actual ground condition, leading to inaccurate understanding of the real soil characteristics especially heterogeneous soil such as peat. Multichannel Analysis of Surface Waves (MASW) is one of the popular methods for measuring the dynamic properties of soil in very low strain. The Kansas Geological Survey first introduced the MASW method in the late 1990s as the improved method for the Spectral Analysis of

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VITA

Kasbi bin Basri was born on June 16, 1991, in Sandakan, Sabah. Resourceful Graduate Research Assistant with more than 6 years of experience in institutional settings. Highly skilled in overseeing research activities and supervising undergraduate students. Talented in guiding all functions relating to research studies, analysis and reporting. The field of interest include geotechnical, geological and geophysical engineering focusing on soft ground such as peat soil and soft clay. Obtained a certified graduate engineer registered with Board of Engineer Malaysia (BEM) under the Civil Engineering discipline. Higher academic background begins in 2009, enrolled for Diploma degree in Civil Engineering at Polytechnic Kota Kinabalu. Upon completion on 2012, continued for Bachelor of Civil Engineering (B.Eng.) with Honors from 2012 to 2015 Universiti Tun Hussein Onn Malaysia (UTHM) Johor. In the long run, granted with Master's in Civil Engineering (M. Eng.) – Geotechnical field in 2017 from Universiti Tun Hussein Onn Malaysia with Graduate on Time (GoT). Due to high interest and involvement in research and development to aspire life-long learning, pursued Doctor of Philosophy (PhD) in Civil Engineering in Universiti Tun Hussein Onn Malaysia in February 2018. Up to the present time, many papers had been published in high-impact- factor journal with various indexes. Professional and technical involvement includes private consultation works related to technical specialty in current research activities and industrial attachments in private firm.